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Employing Dynamic Transparency for 3D Occlusion Management: Design Issues and Evaluation

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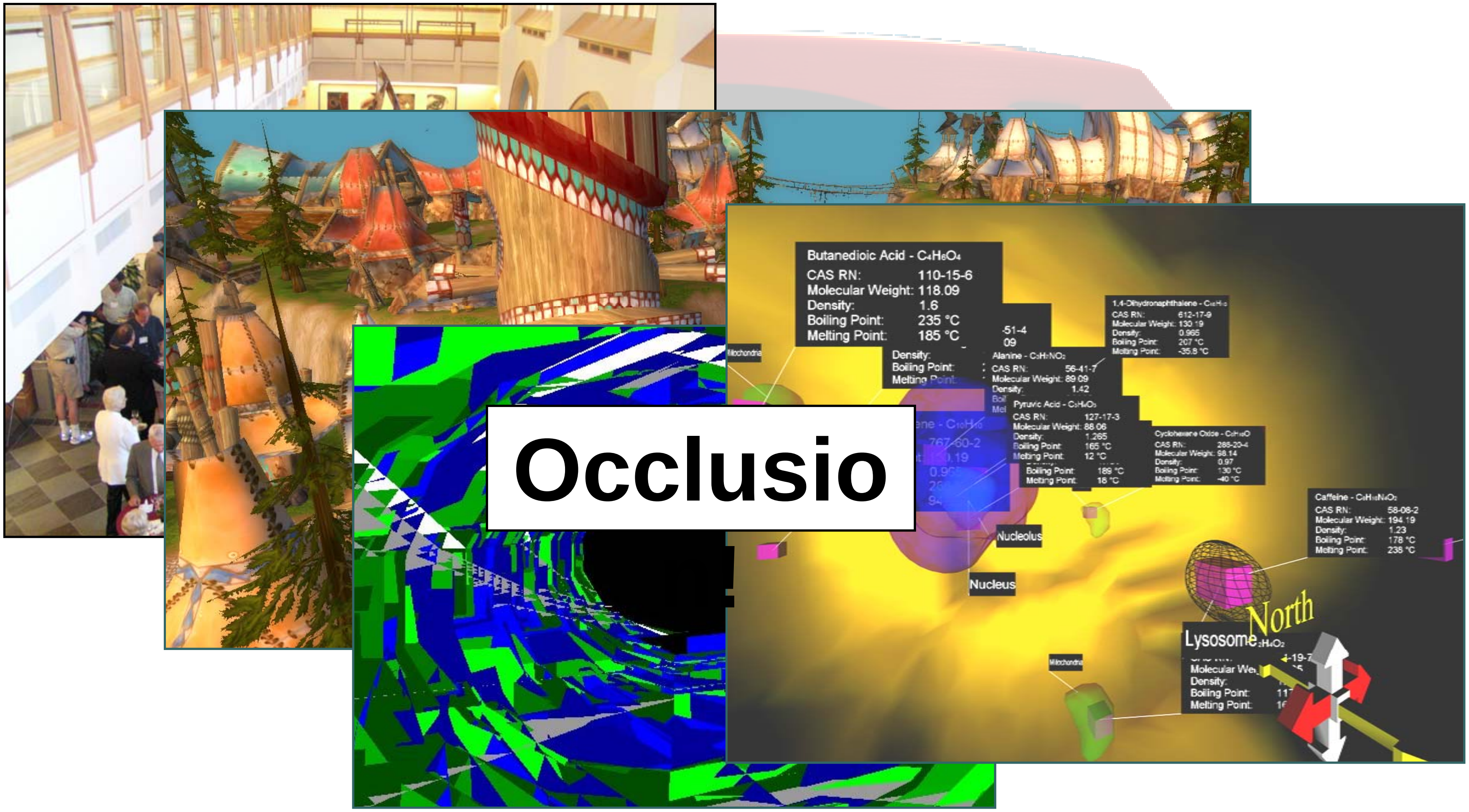
The Least Common Denominator…

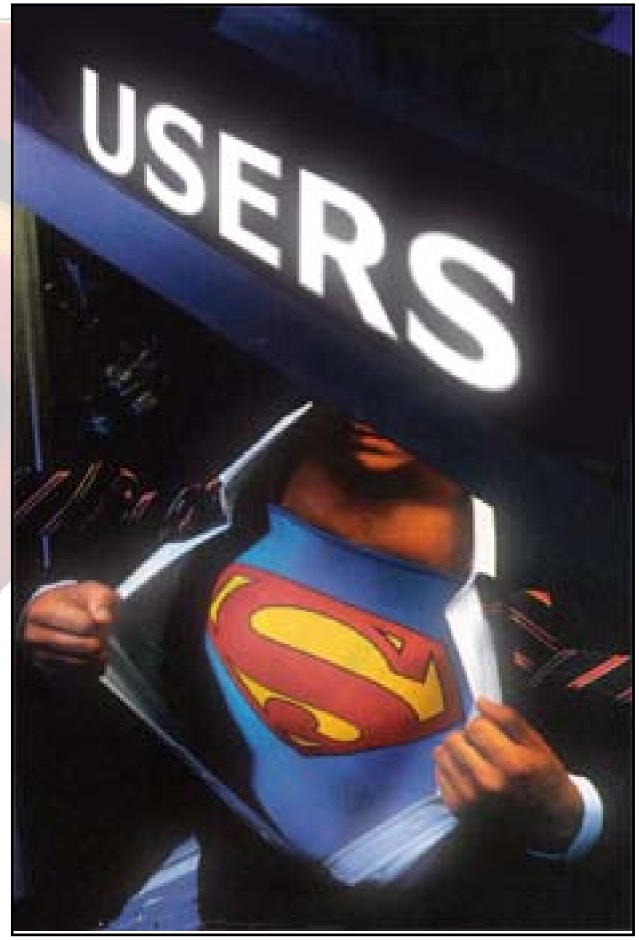


Problem: 3D Visualization

- Information-Rich Virtual Environments (IRVEs)
  - Information visualization in 3D
  - [Bowman et al. 2003]
- IIRVE has a lot of potential but is **tricky**
  - Visibility and legibility of objects
    - **Discover** objects
    - **Access** information encoded in objects
    - **Spatially** relate objects
- **Occlusion** is one of the main causes
- Particularly problematic for 3D visualizations
  - Easier in 2D, but still...
  - ”Cocktail party” effect

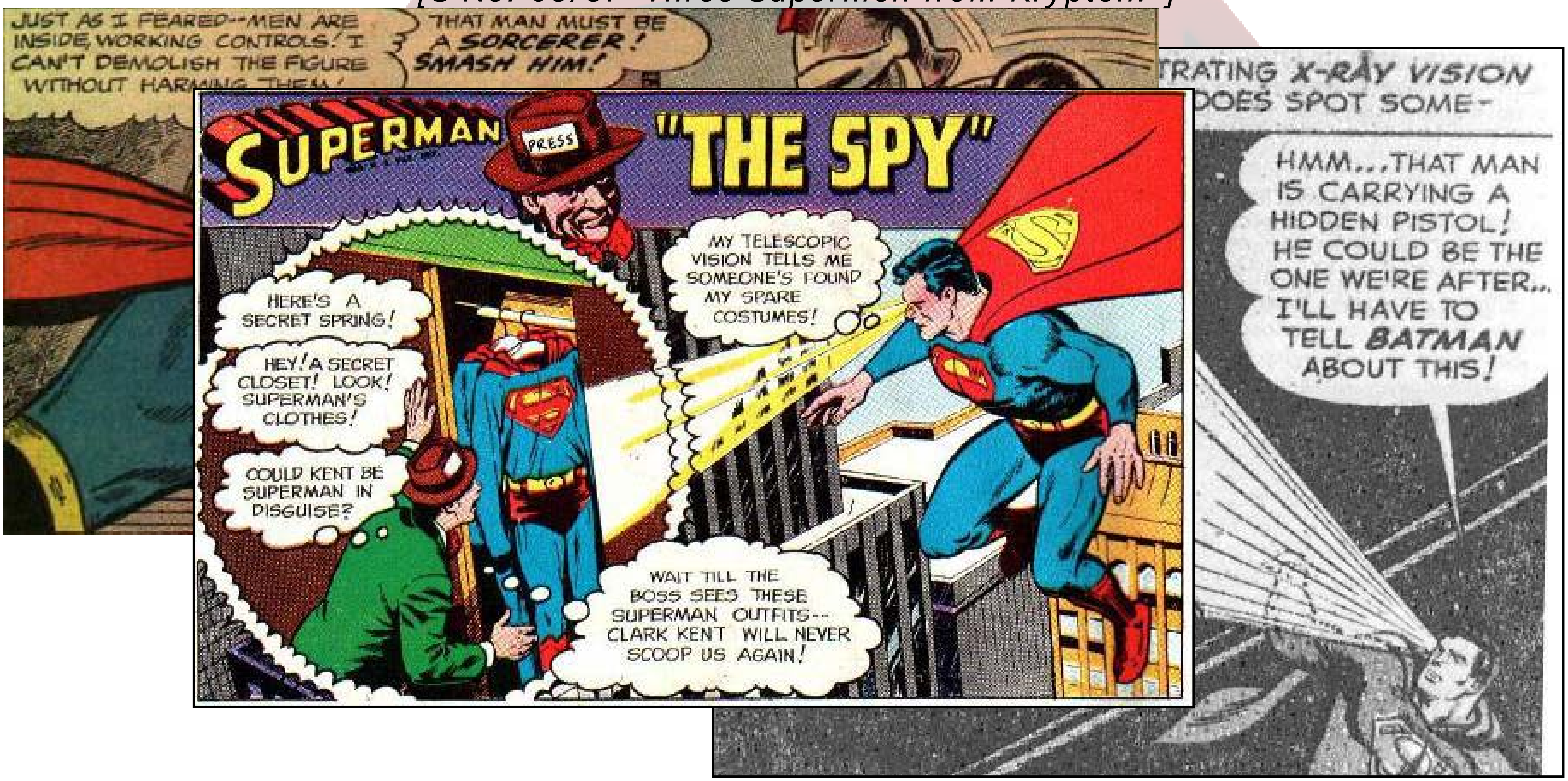
Inspiration

- What if we could endow all human users with **Superman-like** powers of observation?
  - Difficult in the real world
  - Possible in the **computer** world
- **Idea**: Give the users super-human vision
  - See through walls
  - See things far away
  - See things too small to see with the naked eye



Example: Superman's X-Ray Vision

*"Where we come from **everyone** has see-through vision, extra-strength and extra-speed!"*
[S No. 65/3: "Three Supermen from Krypton!"]

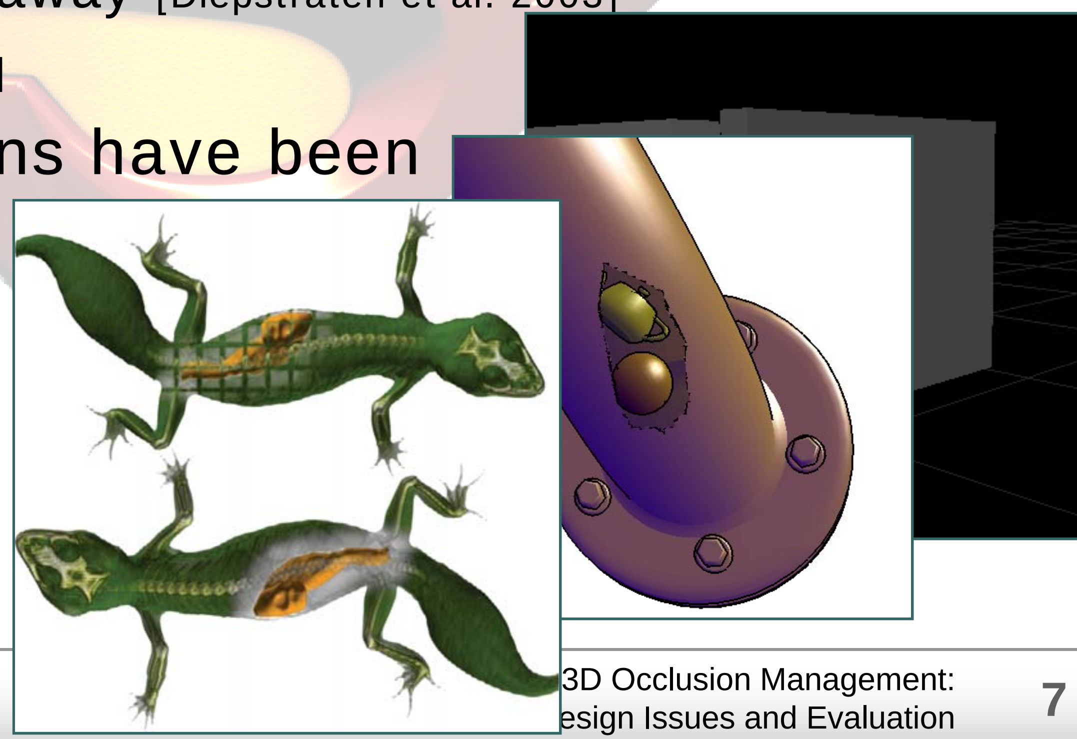


Benefits

- Let us provide our users with X-ray vision!
- X-ray vision has a very important benefit:
  - Avoids the previous problems with **visibility** and **legibility** in 3D environments
  - Can easily pinpoint important **targets** despite occluding **distractors**
- Main stumbling block of 3D information visualization
  - Caused by the nature of the human vision system
    - (But not the superhuman vision system…?)

Dynamic Transparency

- **Idea**: Adjust transparency of surfaces to make targets visible through occluding distractors
- Existing techniques for dynamic transparency
  - Perspective cutouts [Coffin and Höllerer 2006]
  - Interactive break-away [Diepstraten et al. 2003]
  - IDVR [Viola et al. 2004]
- No user evaluations have been performed



Dynamic Transparency Model

- We define our model for dynamic transparency as a set of rules:
  - **R1**: All important objects (targets) in a scene should be visible from any given viewpoint
  - **R2**: Targets are made visible by changing the transparency level of occluding surfaces from opaque (α = 100%) to transparent ($\alpha = \alpha_t$ > 0%) within a cutout area enclosing the object
  - **R3**: Some surfaces are impenetrable and will never be made transparent (cf lead for Superman)
  - **R4**: Targets are allowed to self-occlude themselves
- **Cutout area**: convex hull (circle) or outline with a gradient transparency border

Image-Space Dynamic Transparency

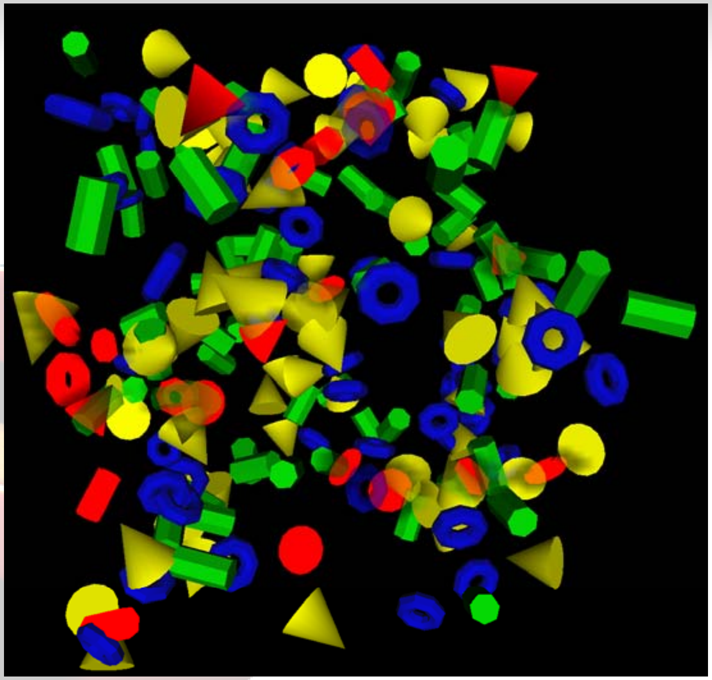
- **Observation**: The image space is perfect for detecting instances of occluded targets and dynamically adjusting transparency to allow the user to ”see through” surfaces
  - Can employ fragment and vertex shader capabilities of modern programmable graphics hardware
  - Achieve Superman-like ”cutaway effect” of surfaces to retain **depth cues** and spatial information
- Our algorithm renders targets into an offscreen buffer and alpha blends on frame buffer to achieve Superman-like X-ray vision

Screenshots

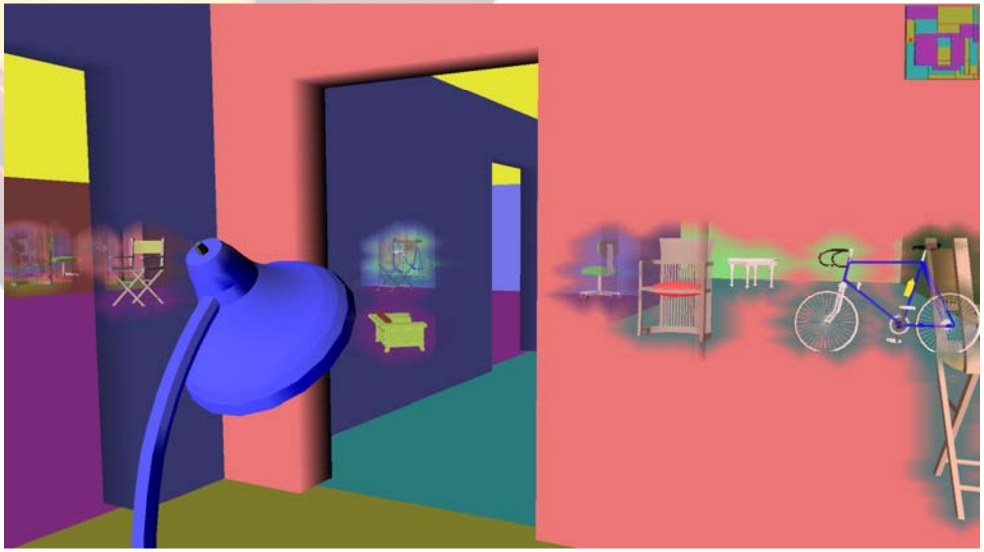
User Study

- **Hypothesis**: Users perform visual perception tasks better with dynamic transparency
  - (Loss of depth cues and increased visual complexity will not be a major factor)
- **Comparison**: standard 3D camera navigation
- **Subjects**: 16 paid participants (13 male, 3 female)
- **Factors**: `dyntrans`
  - Dynamic transparency **on** or **off**
- Repeated-measures within-subject design

Tasks and Worlds



- **Abstract 3D World:**
  1. **Count** number of targets
  2. **Identify** the pattern formed by targets



- **Virtual Walkthrough**:
  3. **Find** unique target
  4. **Count** number of targets

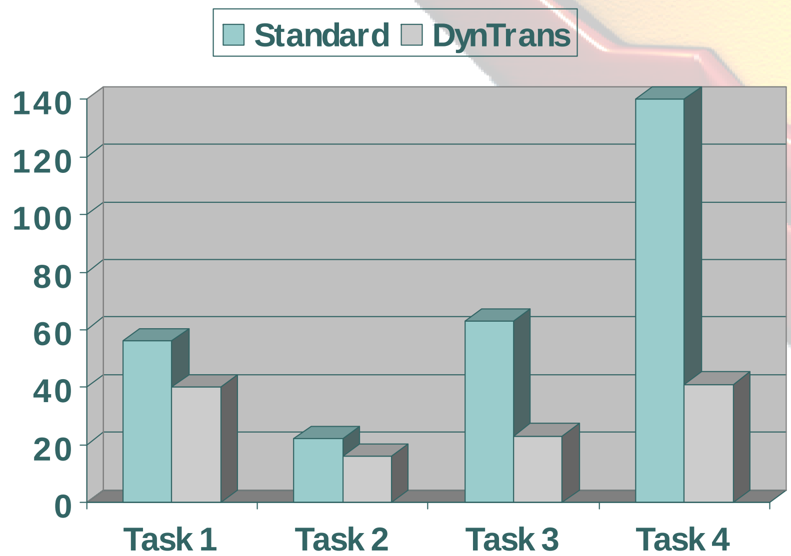
Results

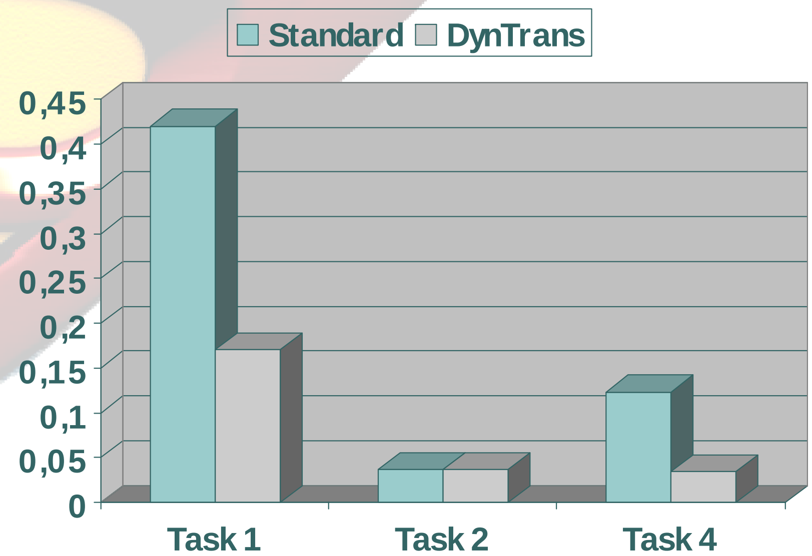
Completion time

- Averages for all tasks:
  - Standard: 65 seconds
  - Dyntrans: 29 seconds
  - Significant ($p < 0.05$)

Errors

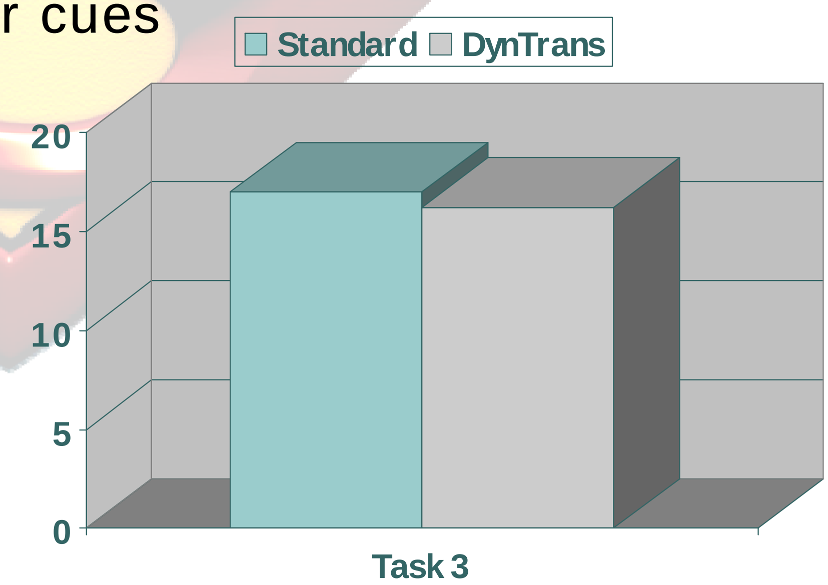
- Task 1, 2, 4: errors per total number of targets
- T1 significant, others not





Discussion

- Task 3 shows the accuracy of marking an object on a 2D map
  - Dyntrans has no adverse effect on depth cues
- Occlusion is still an important depth cue
  - Avoid “reverse occlusion”!
  - Use cutout shape + other cues
- **Observation**: Users respect world more with no dyntrans



Conclusions

- Superhero X-ray vision has an important benefit
  - Avoids **visibility** and **legibility** problems by allowing for occluding surfaces to be made (semi-)transparent
- Our model for dynamic transparency supports this mechanism in visualization applications
  - Targets are always visible through semi-transparent cutouts in occluding distractors
- Results from our user study:
  - Dynamic transparency allows for solving visual perception tasks faster and with generally better or equal accuracy to standard 3D navigation
- Depth cues is an issue...

Questions?

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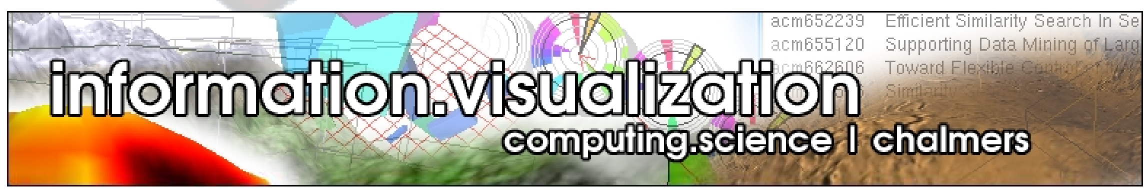

On Superhero X-Ray Vision

*"Today's Superman possesses a wide range of optical super-powers, including **X-ray vision**, which enables him to see through all substances except lead; **telescopic vision**, which enables him to focus on objects millions of miles away; **super-vision**, a combination of X-ray vision and telescopic vision, which enables him to perform such optical feats as peering through the wall of a house thousands of miles away; **micro-scopic vision**, which enables him to examine the tiniest atomic particles…"*

SUPERMANICA
THE ENCYCLOPEDIA OF SUPERMANIC BIOGRAPHY

- **Sources**: Supermanica (supermanica.info) and the Superman Encyclopaedia (theages.superman.ws/Encyclopaedia/)
- Major components:
  - **X-ray vision**: see through all substances and materials except lead
  - **Telescopic vision**: see (very) distant objects
  - **Supervision**: combination of x-ray and telescopic vision
  - **Microscopic vision**: see on a microscopic scale